10/500596
DT12 Rec'd PCT/PTO 29 JUN 2004

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DETERMINATION OF OPTICAL PROPERTIES OF A DEVICE UNDER TEST IN BOTH DIRECTIONS IN TRANSMISSION AND IN REFLECTION

BACKGROUND OF THE INVENTION

The present invention relates to determination of optical properties, e.g. polarization dependent loss (PDL), polarization mode dispersion (PMD), differential group delay (DGD), insertion loss, return loss and/or chromatic dispersion (CD), of a device under test (DUT) in both directions in transmission and in reflection of an optical beam.

Measurement setups for the above-mentioned purpose shall be as easy as possible to handle and shall reveal all optical properties of the DUT as fast as possible and with as little handling as possible. This means that the DUT should be fully characterized to all parameters required when it is once connected to the measurement setup. For a full characterization it is required to measure all parameters both in transmission and in reflection as fast as possible.

From the disclosure of work of Sandel et al (David Sandel, Reinhold Noé, "Optical Network Analyzer applied for Fiber Bragg Grating Characterization", ECOC 97, 22-25 September 1997, Conference Publication No. 448, © IEE, 1997, pp. 186-189; David Sandel et al, "Optical Network Analysis and Longitudinal Structure Characterization of Fiber Bragg Grating", Journal of Lightwave Technology, Vol. 16, No. 12, December 1998, pp. 2435-2442) it is known a method for polarization-resolved optical fiber Bragg grating characterization. However, in these disclosures only the reflection of the DUT is measured.

From a work of Froggatt at al (Froggatt et al, "Full Complex Transmission and Reflection Characterization of a Bragg Grating in a Single Laser Sweep",) it is known a measurement setup to measure the group delay of a DUT in transmission and in reflection in both directions.

However, with the disclosed measurement setup it is not possible to measure PMD or PDL. Moreover, the measurement setup disclosed in this article causes problems because to enable the detectors used to detect the signals of reflection and

transmission of both directions simultaneously, i.e. the reflected signal of one direction superimposed with the transmitted signal of the other direction and the transmitted signal of one direction superimposed with the reflected signal of the other direction, differences between the measurement and the reference path lengths are necessary to distinct between these signals without really knowing all impacts of these differences.

Also the different path lengths for the various signals put additional requirements onto the receiver characteristics and the DUT characteristics which may be problematic for an accurate measurement.

SUMMARY OF THE INVENTION

Therefore, it is an object of the invention to provide improved determination of optical properties of a DUT in both directions in transmission and in reflection of an optical beam.

The object is solved by the independent claims.

An advantage of the present invention is that the DUT can be characterized with as little handling as possible. This means that the DUT can be fully characterized to all parameters required when it is once connected to the measurement setup. I.e. without handling of the DUT all transmission and reflection parameters can be measured in both directions.

In an embodiment of the invention this can be realized by using a switch to direct the incoming light to one of the ports of the DUT. This allows full characterization of the DUT by two wavelength sweeps of the tunable laser source to measure all parameters required for both directions without handling the DUT.

In another embodiment of the invention the switch is replaced by a beam splitter to provide the DUT with the laser beam from both directions simultaneously. Here the two fractions of the light propagating through the DUT in opposite directions are coded by two modulation frequencies. Then, the signals are detected by using a phase sensitive detection scheme, i.e. by a frequency selective detection.

Other preferred embodiments are shown by the dependent claims.

It is clear that the invention can be partly embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

Fig. 1 shows a first measurement setup according to the present invention; and

Fig. 2 shows a second measurement setup according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now in greater detail to the drawings, Fig. 1 shows a first embodiment 1 of a measurement setup according to the present invention for determination of optical properties of a DUT 6 in transmission and in reflection in both directions.

Measurement setup 1 contains a tunable light source 70 which provides a coherent laser beam 72 to a polarization controller 74 (which can be a Hewlett-Packard HP 8169A). The polarization controller 74 provides a polarization controlled coherent light beam 76 to an isolator 78. Optically connected with the isolator 78 and receiving a coherent light beam 80 from the isolator 78 is a switch 81. The switch 81 is not located in the interferometric part of setup1. Optically connected with the switch 81 is a first beam splitter 82 which is a 3dB coupler. Also optically connected with the switch 81 is a second beam splitter 83 which is 3dB coupler, also. Connected to both couplers 82 and 83 is a reference arm 2 and a measurement arm 86.

In the measurement arm there is provided a seat 90 to receive the DUT 6. The seat

90 has two connectors 92 and 94 to enable the DUT 6 to be connected to the measurement arm 86.

In the reference arm 2 there is provided a seat 10 to receive an element 12 being 50% reflective and 50% transparent. Other ratios are possible. The seat 10 has two connectors 4a and 4b to enable the element 12 to be connected to the reference arm 2. The element 12 can further contain an adjustment element to balance the optical path lengths in setup 1, e.g. a variable delay line to allow for different lengths of the path length through the DUT 6. Alternatively and preferred, this problem can be addressed by a sufficiently narrow spacing of the measurement points in the wavelength/frequency domain. For further details of the function of the element 12 it is referred to the European patent application EP-A- 0 111 817 of the applicant. Therefore, the description of element and measurement setup given in the aforementioned application is incorporated herein by reference.

Such a measurement setup 1 can be calibrated and/or verified by a calibration and/or verification element disclosed in European patent application EP-A- 0 111 833 of the applicant. For calibration and/or verification the calibration and/or verification element is inserted in seat 10. Therefore, the description of the calibration and/or verification of the measurement setup with the calibration and/or verification element given in the aforementioned application is incorporated herein by reference.

Connected to the coupler 83 is a polarization diversity receiver (PDR) 106 to detect a superimposed signal being the superposition of the transmitted signal by the DUT 6 and a reference signal coupled in by the coupler 83 from the reference arm 2 when the switch 81 is in its position according to the solid line in Fig. 1. In this case the reference signal is coupled into the reference arm 2 by the coupler 82. If the switch 81 is in its position according to the dotted line then the PDR 106 detects a superimposed signal being the superposition of the reflected signal by the DUT 6 and a reflected reference signal coupled in by the coupler 83 from the reference arm 2. In this case the reference signal is coupled into the reference arm 2 by the coupler 83.

Connected to the coupler 82 is also a PDR 108. PDR 108 detects the superimposed signal of the reflected signal from the DUT 6 coupled in by the

coupler 82 from the reference arm and the reflected reference signal coupled in from the reference arm 2 coming from the element 12 when the switch 81 is in its position according to the solid line in Fig. 1. In this case the reference signal is coupled into the reference arm 2 by the coupler 82. If the switch 81 is in its position according to the dotted line then the PDR 108 detects a superimposed signal being the superposition of the transmitted signal by the DUT 6 and a transmitted reference signal transmitted by element 12. In this case the reference signal is coupled into the reference arm 2 by the coupler 83.

For further details it is referred to the European Patent Application 00125089.3 of the applicant the disclosure of which is incorporated herein by reference.

Fig. 2 shows a second embodiment 200 of a measurement setup according to the present invention. Contrary to the embodiment 1 of Fig. 1 embodiment 200 of Fig. 2 has no switch 81. Instead in setup 200 a shunt 281 replaces switch 81. The shunt 281 provides the reference arm 2 and the measurement arm 86 with the signal 80, simultaneously. To distinct the signals propagating through the DUT 6 the two fractions of the light propagating through the DUT in opposite directions are coded by two different modulation frequencies f1 and f2 provided by two modulation units 201 and 202 providing a signal 80-f1 and a signal 80-f2. Then, the signals 80-f1 and 80-f2 are detected by using a PDR 206 and a PDR 208 having a phase sensitive detection scheme, i.e. by a frequency selective detection. Additionally, the element 12 contains a (not shown) modulation units 203 to key all signals transmitted or reflected by the element 12 with a modulation frequency f3.

To clarify the function of the decoding of the signals detected by PDR 206 and PDR 208 the Stokes matrix elements S11, S21, S12 and S22 are depicted in Fig. 2. Elements S11, S21, S12 and S22 can be derived from the coding frequencies f1, f2, f3 as follows:

At PDR 208: S11 = f1+/- f3, S12 = f2-/+f3, and

at PDR 206: S21 = f1+/- f3, S22 = f2-/+f3.